Remote Experiments and Online Games: How to Merge Them?

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***Abstract*—Online games fulfill the basic requirements of learning environments and can provide engaging learning experience for students. The remote experimentations bring to STEM (science, technology, engineering and mathematics) students the ability to practice configuration, deployment, and troubleshooting scenarios in real-life environment on real equipment. These two teaching methodologies are well known, developed and described in the literature. However, the concepts of integration of the remote experimentations and the game setting are yet to be developed. This paper discusses the ideas for such integrations. The emphasis is made on the educational game design and the flow as a positive impact on learning and attitude of the players. Besides the challenges of balancing attractive elements (graphics, sounds) and educational objectives, the design of the games related to remote laboratories needs to be adjusted to contemporary technological conditions.**

***Index Terms*—remote experiments; experiential gaming model; game design; game-based learning.**

I. INTRODUCTION

Science and engineering had become progressively less valued and understood by the broad public since 1980. People struggle to define what it means to be an engineer. New Outlooks in Science & Engineering (Noise) surveyed that only 4% of teenage girls are interested in training as engineers and 14% as scientists compared to 32% who want to be the fashion models [1]. Saying that implies that the society needs a new vision on quality and effectiveness of education and training systems at STEM (science, technology, engineering and mathematics) to get young people excited about and involved in science and engineering. One of the challenges of the instructional design aimed on solving this problem is providing information and learning material and at the same time engaging students and assisting the progress in their experience. Just using of technology and computers along does not motivate "digital native" students anymore. Therefore, learning environment and methodology that will fascinate STEM learners have to be created. One approach is to provide the students with an experimental laboratory. The fundamental benefit of experimenting is encouraging students for innovation and creativity. However, the laboratory equipment is expensive and its maintenance is complicated.

The remote laboratory reduces the costs significantly, makes laboratory experiments available almost at any time and everywhere [2, 3, 4]. Another approach is to introduce online computer games, which may develop a new learning culture matching the students´ habits and interests [5].

This paper discusses the possibility to combine these two teaching methodologies of remote laboratory and game-based learning. The main purpose of this paper is to present the concept of the game-remote experiment integration and the importance of applying and balancing challenges of game design and remote laboratories design in order to generate the optimal learning experience.

II. REMOTE LABORATORY

A Remote Laboratory is a software and hardware system that enables students to use real experiments physically located in a University. This way, students can access real experiments 24 hours a day, 7 days a week, even including holidays, from anywhere with access to the Internet. Given that the experiments are real, the Remote Laboratories have the opportunity to demonstrate them to the students (i.e. with a webcam) such that the students don't lose the feeling that they are doing exactly what they would do in a hands-on-lab session.

The Remote Laboratory developed at the University of Deusto - WebLab-Deusto - has a variety of different experiments. In the FPGA experiment, the student works with the Xilinx IDE at home and develops a program for a FPGA device [6, 7]. Once the student has finished writing the code, he can connect to the Remote Laboratory, send the program generated in the first step, which is programmed in a real FPGA, and finally interact with it. During limited amount of time, the student will be able to modify some inputs (switches, buttons, etc.) of the device and see through a webcam the produced outputs (leds, 7-seg, etc.). The number of the experimental sessions in unlimited; however the amount of time for each attempt is limited to allow other students to use the device. At the given timeslot only one student can program and control the experiment.

Remote Laboratories also provide an efficient performance of the devices to the University. Many experiments do not require a continuous connection to the device. For example, in the FPGA experiment described above, the device is only used by the student during the small amount of time in which the device is programmed and tested. This amount of time is sufficient for testing if the code is correct or what fails. After this time, the user returns to the IDE to fix the problems, and then tests again by connecting to the experiment. If the device is occupied by another user, the latter student will enter a queue and stay there until all the users that entered before him have finished. If there are many users, the University can put several copies of the same experiment, thus the students will automatically use different experiments and the waiting time in the queue will decrease. Due to this transparent and efficient sharing protocol, the Remote Laboratory might achieve higher levels of throughput per device than traditional laboratories.

For this reason students have the ability to practice configuration, deployment, and troubleshooting scenarios in real-life environment on real equipment.

III. GAME SETTING

Most researchers conceptualize learning as a multidimensional construct of learning skills, cognitive learning outcomes, such as procedural, declarative and strategic knowledge, and attitudes. For several decades the game-based learning model is applied very successfully in formal education such as military training, medicine, finance, physics, etc. [8].

A. Game-based Learning Model

The main feature of the educational games is merging the instructional content with game characteristics. There are different opinions about what the game characteristics are. For example, Thornton and Cleveland [9] claim that *interactivity* is the essential aspect of a game. Johnston and Felix [10] suggested that the *dynamic visuals, rules, goal* and interaction are the essential features. Another approach [11] stated that the essences of playing are *challenge and risk*. According to Malone[12], four elements of computer games can be defined: *fantasy, curiosity, challenge* and *control*.

Traditionally, "to play a game" and "to have fun" are considered as synonyms. However, fun factor is not magic instrument in the educational game design.

Educational games should encourage players to think like scientists. The game play cycle is typical of experimental science one: "hypothesize, test an idea, get a reaction, reflect on the results, and retest to get better results." Unfortunately, very often games have been and still used in education primarily as an instrument for supporting the practice of factual information. The nature of action-based drill will inspire drill-and-practice thinking rather than action with reflection on outcomes and understanding. This means that players will constantly get math problems like 5x5 memorizing the results, while not understanding the underlying rules that make 5x5= 25. Although improving the total score the player does not enhance the learning, since she or he bases the action solely on the trial and error approach.

On Fig. 1, one can see the Model game-based learning created by Garris, Ahlers, and Driskell [13]. At this model the achievement of the learning outcomes occurs outside the game during debriefing and reflection. Debriefing provides a link between the game world and the real world; it draws a relationship between the game events and real-world events and connects game experience and learning. This is true for declarative knowledge, but to progress in the modern educational games, players must increase their procedural and strategic knowledge such as reflectively exploration of phenomena, probation of the world and construction of the objects directly within the game.

B. Experiential Gaming Model

Games should be designed to be "doable," but challenging, pleasantly frustrating - a flow state for human beings [14]. Flow describes a state of complete involvement and engagement in the activity. In computer-mediated environment flow is broken down into three parts: flow antecedents, flow experience and flow consequences [15]. The flow antecedents include focused attention, a clear set of goals, control, skills, and immediate and appropriate feedback (Fig. 2).

The flow experience is responsible for a merging of action and awareness, concentration, sense of control. The flow experience leads to increase in learning, exploratory behavior, acceptance of information technology. The antecedents, speed and intuitive use [16] create flow framework usability. All three components, person, task and tool, should be taken into account when designing educational games. When the task and the use of the tool are complex, then user's attention will be detract. Bad usability decreases the likelihood of flow experiencing task because the player has to spend attention and cognitive resources to inappropriate activity.

The user performance in the game world depends on the previous knowledge and experiences of the user. If system can provide the learner the challenges that are closely matched to the skill level of player, the possibility of flowing becomes higher.

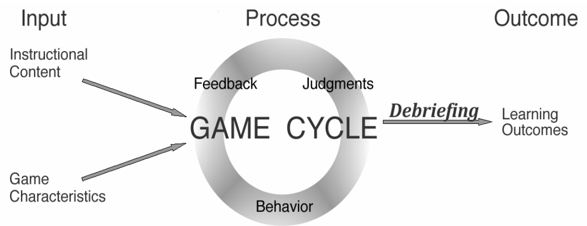

Figure 1. Game-based learning model

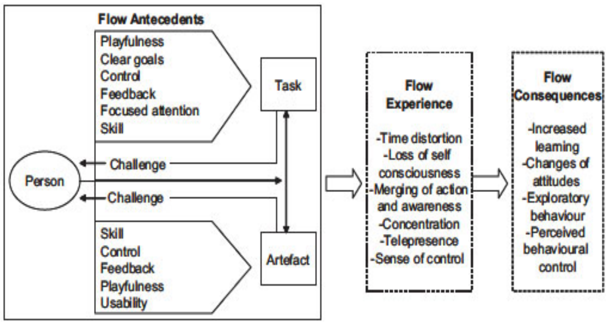

Figure 2. Framework of flow in computer-mediated environments

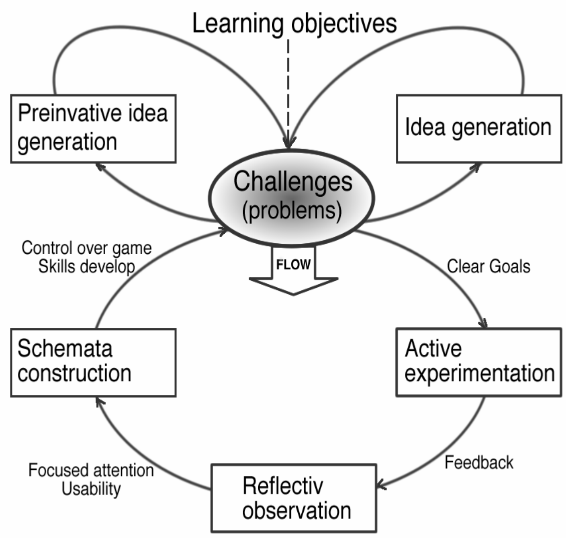

Figure 3. Game-based learning model

The experiential gaming model (Fig. 3) helps to design and analyze educational games [17]. This model takes in account the flow theory and gameplay. We use this model for describing the educational game cycle. In this model the game cycle consists of the ideas loop, experience loop and challenge bank. Challenge bank is responsible for pumping appropriate challenges to learner. To overcome these challenges, the player generates the solutions in the ideas loop. The creation of the solutions is divided into preinvative idea generation and idea generation. Preinvative idea generation is associated with the primary creativity [18]. Then, further solutions are developed and finalized in the idea generation under circumstances of available resources of the game world. After the ideas loop the player tests the solution in the experience loop reflecting outcomes of actions.

Besides the gameplay, the engaging storytelling, appropriate graphics and sound, and game balance play significant role for development of good education game.

C. Storytellings

The producing of story in games is the fundamental part of game design. Usually, every game has some sort of story assigned to it. Story could be just short paragraph that introduces or sets the backgrounds of the game. For example, in *Bureau of Steam Engineering* [19], the game story tells that alternate civil war is begun; an American steam engineer (player) must design and duel steam powered mechanics to defend the Union. The importance of the story depends on the complexity of the game. The more complex the game is, the more significant the story tends to be. Sometimes, the story plays educative role telling the important things about subject of matter while player can apply the information provided to interactive gameplay events.

D. Game Balance

The main objective of the game balance is to design a game, which is consistent, fair and without dominant strategies. Educational games should be balanced so that the success factor of the player will be the gain of the knowledge and skill level of player. Progress in a game is encouraged by positive feedback, collected points and gifts or rewards. In other words, the challenges should be balanced so that the game difficulty increases constantly, step by step, and player has growing interest during the game.

E. Optimizing cognitive load

The main problem of the multimedia learning materials is that the working memory capacity [20] of the learners is often overloaded due to inappropriate ways of material presentation. Traditionally the games consist of rich multimedia elements making the risk of overloading of the working memory capacity of the educational games players high. To overcome the limited capacity problem Mayer [21] presented a cognitive theory of the multimedia learning that assumes that working memory includes limited channels – each channel at one time - for both visual and verbal processing. Thus, the most challenging task of educational game design is to find a balance between attractive elements, such as sounds and graphics, and educational objectives in order to optimize for the players flow and learn appropriate skills as well as the information provided by the game.

Sweller, van Marrienboer, and Paas [22] identified three separate sources of the cognitive load: intrinsic cognitive load that refers to the task nature or subject matter of learning materials; extraneous cognitive load – the manner in which material is presented; and germane cognitive load – the effort needed for the task execution. According to the cognitive load theory, the instructional design cannot change the intrinsic cognitive load. Therefore, the most interesting aspects of the cognitive load theory for the educational game designers are extraneous and germane cognitive loads. Although extraneous cognitive load is determined by the instructional design there is no evidence that reduction of extraneous cognitive load will accumulate unused working memory capacity to a deeper knowledge construction process. According to Kirschner [23], the approach to encouraging learners to engage the cognitive processing works if total cognitive load of instructional design is within the working memory limits. In summary, the cognitive load should be optimized in games by reducing irrelevant multimedia elements, applying modality effect, providing friendly and usable user interface and challenges that support knowledge format.

IV. SEVERAL CASES OF GAME-BASED LEARNING IN STEM

Here we provide a brief description of some examples of game-based learning in engineering.

Robocode [24] is an easy-to-use robotics battle simulator and an open source educational game. The game is designed to help people learn programming concepts, and to program in Java or .NET. The goal of *Robocode* is to develop a robot battle tank to battle against other tanks. The robot battles are running in real-time and on-screen. The simple robot can be written in just few minutes. However, superb robot- fighter can demand many months of work. *Robocode* is used as an introduction to robotics to write code in general, to demonstrate logic flow and decision tools. The game can be played as a single player with non-player robots, but the ultimate goal is to battle against robots designed by other players.

Supercharged! [25] places students in a three dimensional environment where they must navigate a spaceship by controlling the electric charge of the ship and placing charged particles around the space. The goal of *Supercharged!* is helping learners to build stronger understanding and intuition for electromagnetic concepts. Students must carefully plan the trajectory of the spaceship through each level by tracing the field lines that emanate from charged objects, and in the process of doing so, develop a better understanding of how charged particles interact.

PowerUp [26] - online, multiplayer game developed by IBM in partnership with TryScience/New York Hall of Science - focuses on energy, engineering and diversity. The objective of the game is to generate clean energy - when racing to save the planet from ecological disaster. Each area of the energy- themed worlds - water, solar and wind - has a major challenge to be solved, all with four objectives and clear measures of success. Players take on the role of Engineers, working together designing and building energy solutions to save the planet. Conversations with "game" experts and engaging interactive activities allow players to explore ways engineers design and build systems to harness renewable energy sources as alternatives to burning fossil fuels. The gameplay is designed as a story that allows students to experience the excitement and the diversity of modern engineering.

Energize! [27] is a flash based game focusing on economic and environmental impacts resulting from different energy sources. The game was developed by the Orlando Science Center and by a team from the Florida Interactive Entertainment Academy (FIEA). *Energize!* challenges the player to provide electricity to their growing community while keeping emissions minimized. Player has five unique energy sources to choose from: wind, solar, biomass, nuclear, and fossil fuels. Each form has tradeoffs. The player learns that it takes a combination of energy sources to achieve a balance between energy demand, economic needs and environmental concerns.

Moonbase Alpha [28] is a NASA-funded multiplayer puzzle game on a hypothetical lunar outpost in 3-D immersive setting. With precious minutes ticking away, the team of players must repair and replace equipment in order to restore the oxygen production to the settlement on the lunar base. The key to game success is team coordination along with the proper use and allocation of available resources (player controlled robots, rovers, repair tools, etc.). The game shows NASA content – lunar architecture – in amusing way and inspires interest individuals in science, technology, engineering and mathematics fields of study and careers.

V. REMOTE EXPERIMENTS IN GAME ENVIRONMENT

To create a good educational game using remote laboratory experiments the basic steps of game design, remote laboratory construction of experiments, elements of learning, motivation, and engagement outlined below should be taken into consideration:

- determine pedagogical approach (what model you will use, how students will learn)
- situate the task
- elaborate the details
- incorporate underlying pedagogical support
- map learning activities to interface actions
- map learning concepts to interface objects
- analyze the technical limitations of the remote experiments
- create relevant storytelling
- design game balance – balance of challenges and motivation
- optimize cognitive load - avoid irrelevant multimedia elements, provide friendly and usable user interface, and apply modality effect

When designing an educational game we have to reflect upon didactical approach and related topics. We have to ask ourselves “What do we want the learners to learn?” Before defining the activities we should try to provide an answer to the questions “what?”, ”how?”, and “why?”. There are many interactive learning techniques that have already been used in game-based learning. One of those techniques is “learning by doing”, where execution of the remote experiments will teach students that good hypotheses for easy problem may lead to hypotheses that work well for harder problems [28] in order to find creative solutions to complex problems; and think about relationships of facts and actions. The open-ended structures of the educational game let learners to be producers by allowing them to modify or even design new scenario. In the game-based learning making a mistake - or using trial and error - is a primary way to learn and is considered the motivation for players to keep on trying, encouraging to take risks, explore, and try new things.

The most challenging task of the game development with remote laboratory experiments is that the elements of the real world – remote experiments – integrated to the game virtual environment. The technical limitations such as bandwidth, time, interactivity, and simultaneous quantity of the players may have a significant influence on the game design.

Remote experiments integrated into the game setting should provide clear goals that player always knows what to do without extra thinking about it as well as immediate and appropriate feedback to the player actions. Good-designed learning opportunities could be created following the exploratory approach to learning, according to the constructivist learning theory. Interactions, coping with problems, understanding of the whole pattern, etc. are the major characteristics of this theory. From the constructivist point of view learners are active participants in knowledge acquisition, and engaged in restructuring, manipulating, re-inventing, and experimenting with knowledge to make it meaningful, organized, and permanent.

VI. CONCLUSIONS

Education institutions are looking for new methodologies for contemporary fast changing generation of learners. Innovative forms of teaching and learning should be created in order to provide concepts for lifelong learning to their prime customers - learners. Modern industry needs employees proficient in effective communication, teamwork, creative solutions of complex problems, in thinking laterally (not just linearly), and designing good ideas in a world full of high-risk, complex systems. At the same time confidence with contemporary instrumentations and technology is highly desirable for the industrial progress. Is it possible that the future engineers will develop a large portion of these skills by completing remote experiments in the game-based mode? Is this ambitious task? Both the game design and remote experiments are of the crucial importance on how and what students learn. The entire learning process can depend on the details in the game and remote experiment design.

In this paper we researched a concept of integration of the remote experiments into game and stressed on the educational game design and the flow as a positive impact on learning and players attitudes. It was shown that immediate feedback, clear goals, appropriate challenges, and good usability build the harmony in the game world and affect the success of the learning outcomes. It is not enough just to wrap some learning content in a trivia game framework – educational game needs to be closely adjusted to the actual learning content. Design of the gameplay event in the remote laboratories necessarily requires taking into account modern technological challenges of the remote experiments.

The meaningful merging of the two teaching methodologies of remote laboratory and game-based learning can bring significant benefits into pedagogical approach of web-based learning environment. In the future, the concept of integration of remote experiment into game setting will be technologically tested and further developed. This requires a close collaboration between game-design and remote experimentation researchers and developers, and educators, which becomes crucial for the facilitation of the learning experience at the game-remote experimentation setting.

REFERENCES

[1] M. Gould, "Girls choosing camera lenses over microscopes", *The Guardian*.(Oct.03,2008), http://www.guardian.co.uk/education/2008/oct/03/science.choosingadegree. (accessed November 25, 2010).
[2] J. Rodriguez-Andina, L. Gomes and S. Bogosyan, "Current trends in industrial electronics education", IEEE. Trans. on Industrial Electronics, Vol 57, Nº 10, pp. 3242-3244, October 2010, ISSN: 0278-0046.
[3] L. Gomes and S. Bosgoyan, "Current trends in remote laboratories", IEEE. Trans. on Industrial Electronics, Vol 56, Nº 12, pp. 4744-4756, December 2009, ISSN: 0278-0046.
[4] García Zubía, J. “Programmable Logic and WebLab”, Proceedings of the 5th European Workshop on Microelectronics Education, Lausanne (Switzerland), April 2004, ISBN:1-4020-2072-4, pp. 277-282.
[5] M. Prensky, Digital Game-based Learning. McGraw-Hill, 2001.
[6] J.García-Zubia, D. Lopez-de-Ipiña, P. Orduña, U. Hernández, and I. Trueba, “Evolution of the WebLab at the University of Deusto” *EWME 2006*, Stockholm (Sweden), June 2006.
[7] J.García-Zubia, J. Sanz Martinez, B. Sotomayor and JM. Saenz, “A new approach to educational software for logic analysis and design” *IADAT Journal of advanced technology*, 2004, pp. 25-28, ISSN 1698-1073.
[8] M.Pivec, O.Dziabenko, “Game-Based Learning in Universities and Lifelong Learning: “UniGame: Social Skills and Knowledge Training” Game Concept,” Journal of Universal Computer Science, vol. 10, no. 1, pp.14-26, 2004.
[9] G.C. Thornton and J.N. Cleveland, “Developing managerial talent through simulation,” American Psychologist, vol.45, pp.190-199, 1990. doi:10.1037/0003-066X.45.2.190
[10] R.T. Johnston and W.de Felix,” Learning from video games,” Computer in the Schools, vol.9, pp. 199-233, 1993.
[11] M. Baranauskas, N. Neto, and M. Borges, “Learning at work through a multi-user synchronous simulation game,” Proceeding of the PEG’99 Conference, Exeter, 1999, UK(137-144). Exeter, UK: University of Exeter.
[12] T.W. Malone, ”What makes computer games fun?,” Byte, vol.6(12), pp.258-277, 1981.
[13] R.Garris, R.Ahlers. and J.E.Driskell, “Games, motivation and learning,” Simulation & gaming; An Interdisciplinary Journal of Theory, Practice and Research, vol.33, No.4, 2002.
[14] M. Csikszentmihalyi, Flow: The psychology of optimal experience, New York: Harper Collins, 1990
[15] H. Chen, R. Wigand and M.S. Nilan, “Optimal experience of web activities,” Computers in Human Behavior, vol. 15, pp. 585–608, 1999. doi:10.1016/S0747-5632(99)00038-2
[16] Y. X. Skadberg and J. R. Kimmel, ”Visitors’ flow experience while browsing a web site: its measurement, contributing factors, and consequences,” Computers in Human Behavior, vol.20, pp.403–422, 2004. doi:10.1016/S0747-5632(03)00050-5
[17] K. Kiili, “Digital game-based learning: Towards an experiential gaming model,” Internet and Higher Education, vol.8, pp.13–24, 2005. doi:10.1016/j.iheduc.2004.12.001
[18] A.Maslow, “The creative attitude,” The Structurist, vol.3, pp.4–10, 1963.
[19] Zachtronics Industries, 2010, "The Bureau of Steam Engineering"[online video game], http://www.zachtronicsindustries.com/the-bureau-of-steam-engineering/ (accessed Dec.1, 2010).
[20] K. Kiili, “Learning with technology: cognitive tools in multimedia learning materials,” Proceedings of ED-MEDIA 2004,world conference on educational multimedia, hypermedia & telecommunications, Switzerland, 2004.
[21] R.E. Mayer, and R. Moreno, R. “ Aids to computer-based multimedia learning,” Learning and Instruction, vol.12, pp.107–119, 2002. doi:10.1016/S0959-4752(01)00018-4
[22] J. Sweller, J. J. G. van Merrienboer and F.G.W.C. Paas, “ Cognitive architecture and instructional design,” Educational Psychology Review, vol.10, pp.251–296, 1998. doi:10.1023/A:1022193728205
[23] P.A. Kirschner, “Cognitive load theory: implications of cognitive load theory on the design of learning,” Learning and Instruction, vol.12, pp.1–10, 2002. doi:10.1016/S0959-4752(01)00014-7
[24] M. Nelson and F. N. Larsen, 2001, " Robocode "[open source online video game], http://robocode.sourceforge.net/ (accessed Dec.3, 2010).
[25] The Education Arcade , 2005, "Supercharged!"[online video game], http://www.educationarcade.org/supercharged (accessed Dec.1, 2010).
[26] IBM , TryScience,New York Hall of Science,2008, "PowerUp"[video game], http://www.powerupthegame.org/home.html (accessed Dec.3, 2010).
[27] Orlando Science Center (OSC) and Florida Interactive Entertainment Academy (FIEA), 2010, "Energize" [videogame], http://www.energizegame.com/ (accessed Dec.1, 2010).
[28] Army Game Studio, Virtual Heroes, Applied Research Associates in Research Triangle Park, N.C.,2009, "Moonbase Alpha"[video game], http://www.nasa.gov/offices/education/programs/national/ltp/games/moonbasealpha/index.html (accessed Dec.1, 2010).
[29] J.P. Gee, What video games have to teach us about learning and literacy. New York: Palgrave/Macmillan, 2003

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